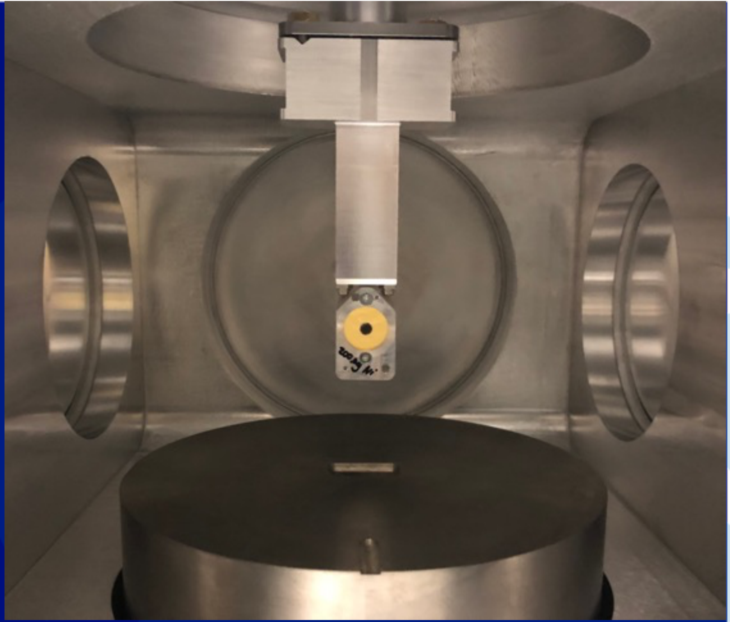
Los Alamos NATIONAL LABORATORY

First LANSCE result on differential cross sections of the $^{16}O(n,\alpha)^{13}C$ reaction



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Theoretical Division: G. Hale, M. Paris
[&] currently at ORNL

IAEA Technical Meeting on (alpha,n) nuclear data evaluation and data needs

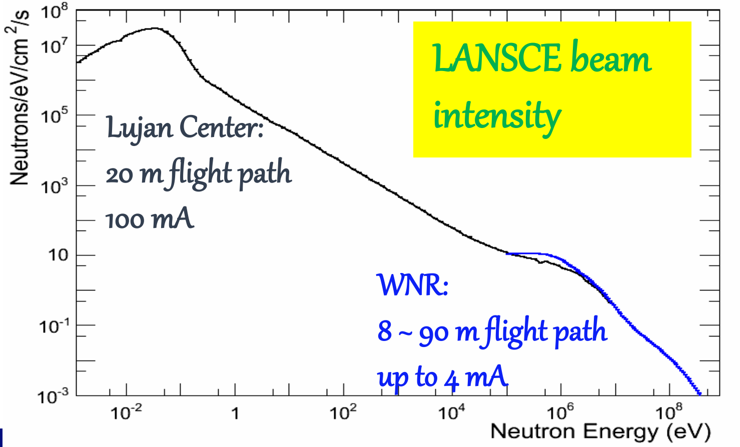
Nov. 8 - 12 2021

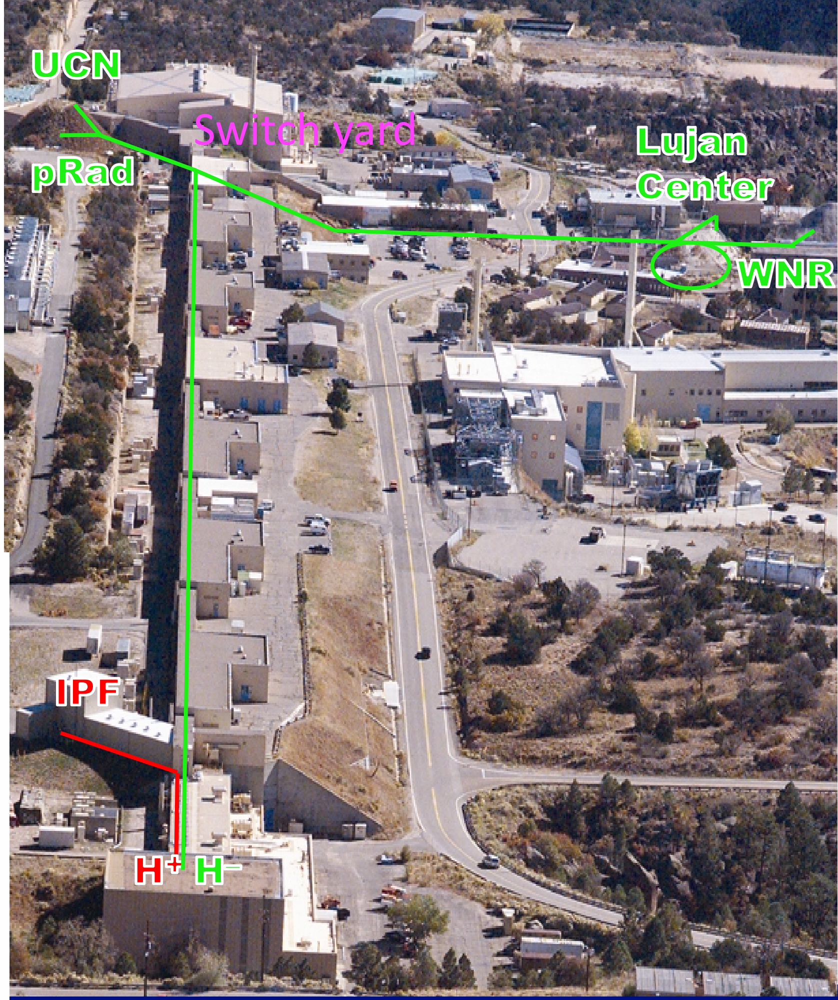
LANSCE is a multidisciplinary accelerator complex serving multiple missions

- Uniquely capable of accelerating 800 MeV of H^- and 100 MeV of H^+ simultaneously, with 120 pulses per second shared among 5 facilities
  1. Isotope Production Facility (DOE-Office of Science)
  2. Proton Radiography (DOE-NNSA)
  3. Ultra-Cold Neutron Source (DOE-Office of Science)
  4. Lujan Center (DOE-NNSA)
  5. Weapons Neutron Research (WNR) Facility (DOE-NNSA)

LANSCE beam energy

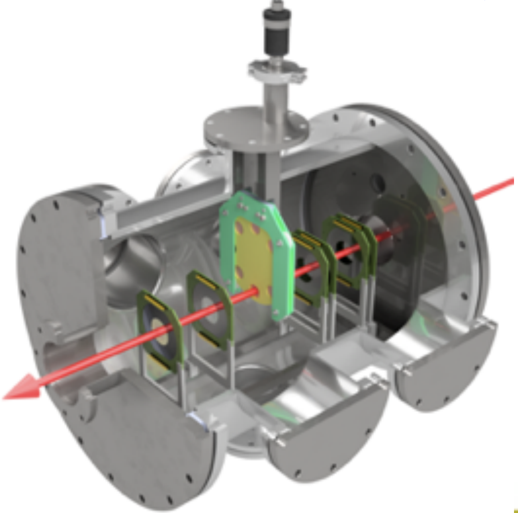
Lujan Center
-thermal ~ 100 keV
WNR
-100 keV ~ 600 MeV



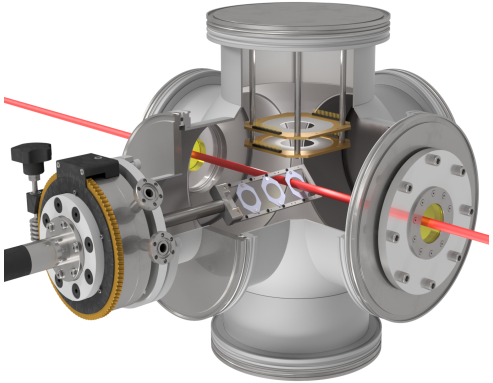


(n,z) Differential Measurement Effort using Low Energy NZ (LENZ)

LENZ: for stable isotopes (^{12,13}C, ^{16}O, ^{35}Cl, Fe, Ni, Cr, As,...)

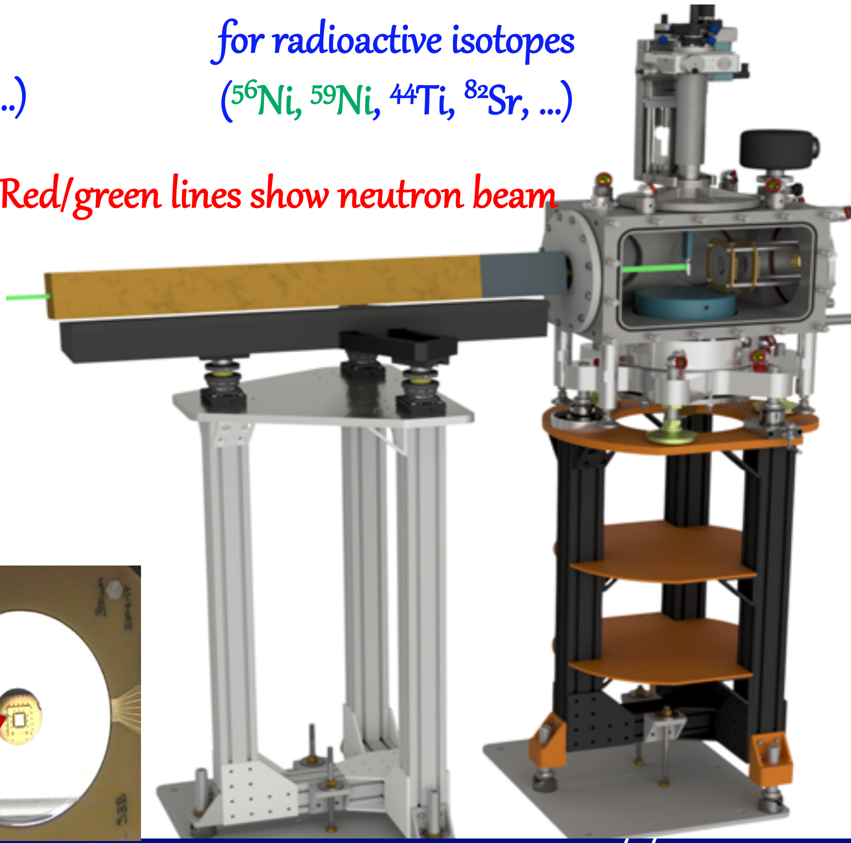


ALSOLENZ: optimized for around 90 degree angles (^{54}Fe, ^{56}Fe, ^{58}Ni, ^{60}Ni, Cr, ^{75}As, ...)

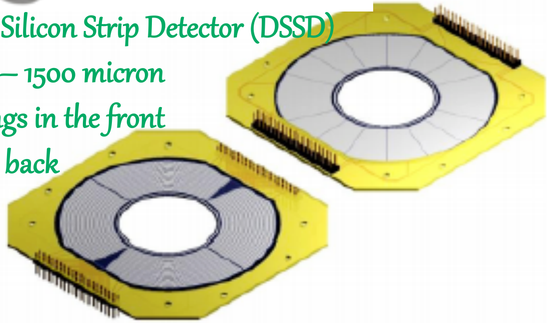


hotLENZ: for radioactive isotopes (^{56}Ni, ^{59}Ni, ^{44}Ti, ^{82}Sr, ...)

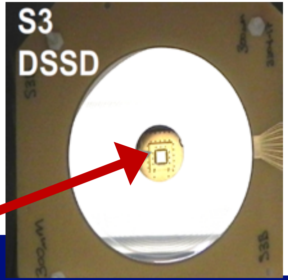
Red/green lines show neutron beam



Double-sided Silicon Strip Detector (DSSD)
- thickness: 40 – 1500 micron
- concentric rings in the front
- wedges in the back



4 X4 mm^2, 500 µm thick chemical vapor deposition (CVD) Diamond detector



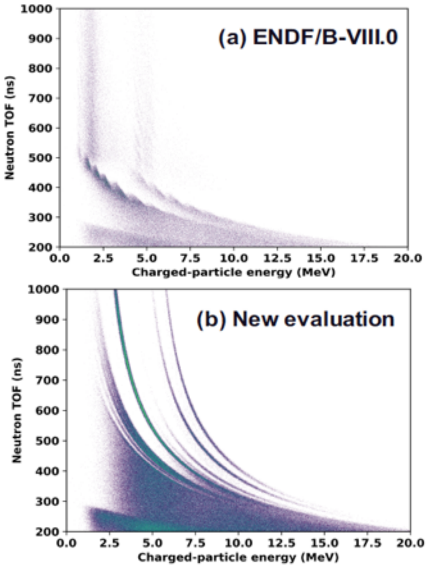
Validating MCNP simulations with LENZ data

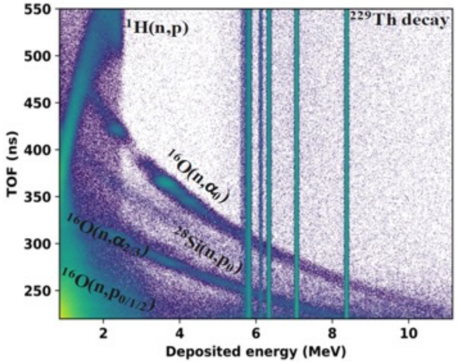
Votaw, Zavorka, Lee, et al. NIMA (soon to be submitted)

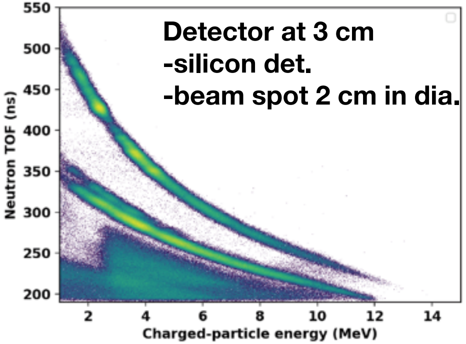
1. Testing if nuclear library is adequate for charged particle transport
2. Improving experimental timing and energy uncertainties in LENZ configuration
3. Reducing Neutron beam induced backgrounds in detecting charged particles in TOF facility

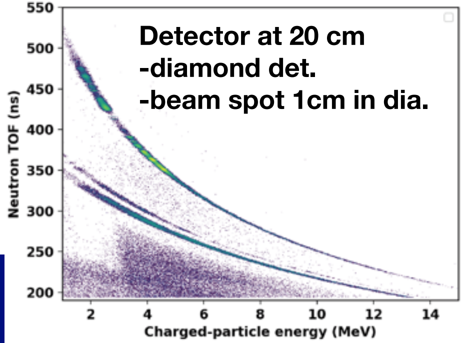
Kim, Lee, Kawano et al. NIMA 964, 163699 (2020)

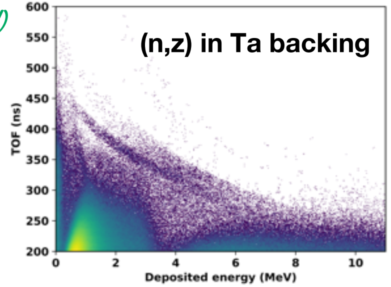
^{59}Ni(n,z) reaction



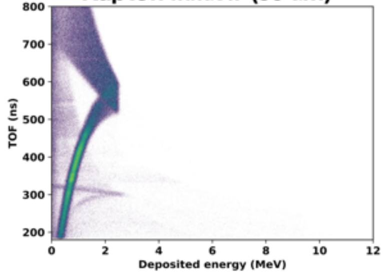




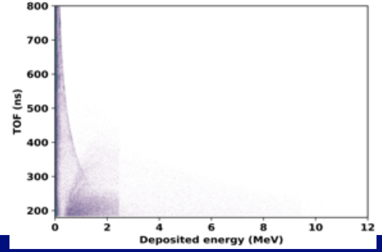




Kapton window (50 um)

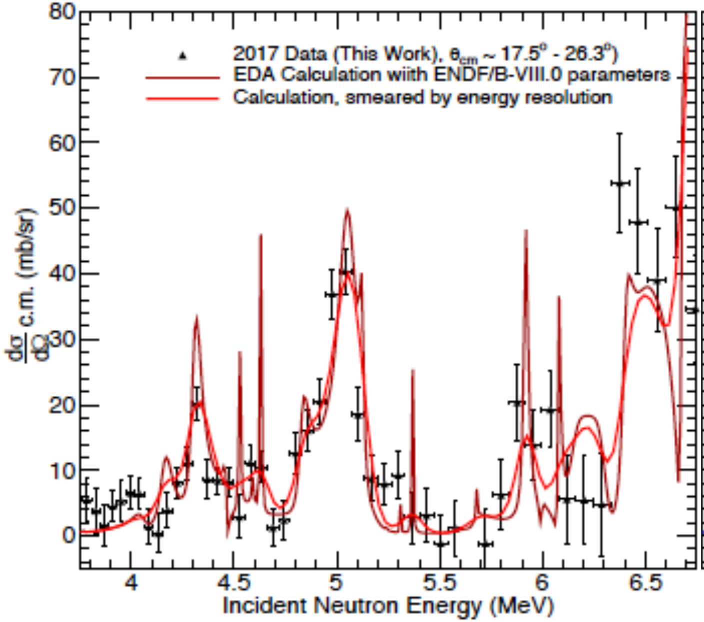


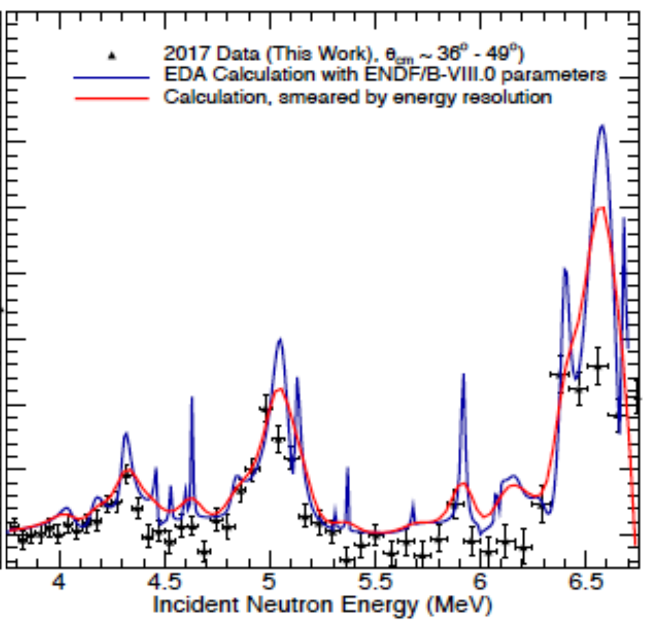
Al window (100 um)

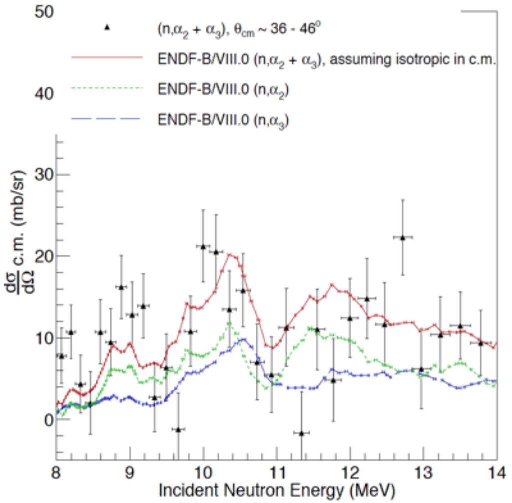


2017 LENZ $^{16}O(n,\alpha)$ differential cross sections

1. Angular response functions are provided by MCNP simulations
2. (n,α_0) and $(n,\alpha_2+\alpha_3)$ angular distributions are deduced from this work
3. LENZ (n,α_0) angular distributions well agreed with ENDF/B-VIII.0

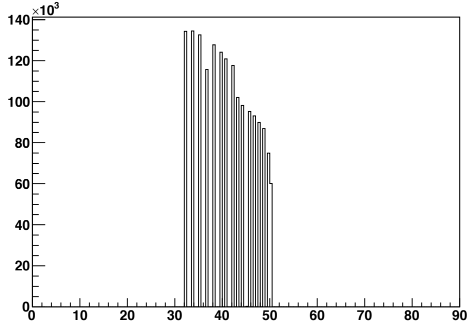




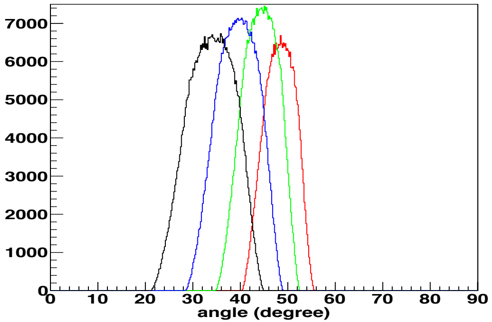


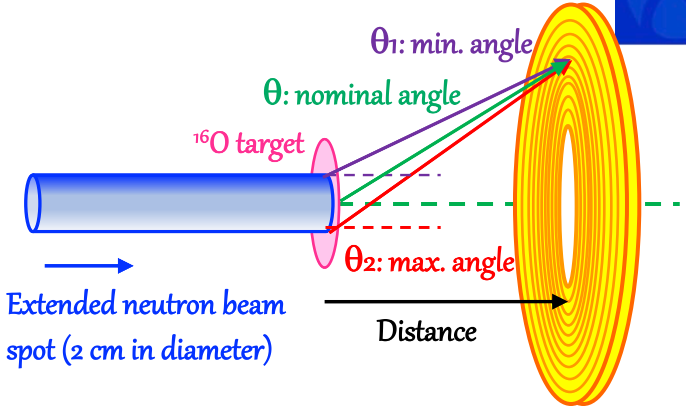
LENZ $^{16}O(n,\alpha_0)$ angular resolutions, estimated in MCNP

Emitted charged particle's angles in each ring of silicon detector



detected charged particle's angles determined in each ring of silicon detector



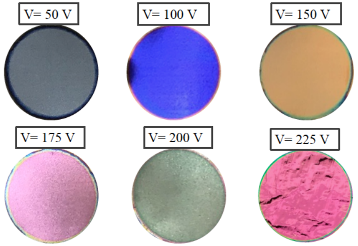


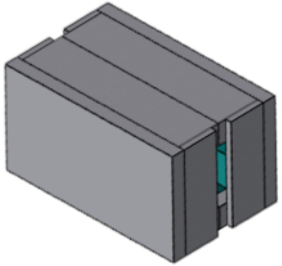
- With detected ring # in silicon, nominal angles are determined by assuming the reaction point at the origin (0,0,0)
- Due to this realistic beam size and the distance between the sample and the detector, each ring's actual angular coverage ($\theta_2 - \theta_1$) was found 8-18 degrees in LENZ 2016 data sets

$^{16}O(n,\alpha)$ LANSCE dedicated run in 2021, to reduce systematic uncertainties

1. Reduce neutron scattering at a sample: new oxidized samples (Ta2O5) will be made in order to reduce the Ta backing thickness from 125 μm to 3 μm.
2. Utilize the secondary sweeper magnet right after the collimation: this reduces any secondary charged particles entering to silicon detectors immensely.
3. Replace the vacuum window from Kapton to a thin Al foil: this removes any additional protons produced from (n,p) scattering on hydrogens in the window.
4. Increase the distance between the sample and DSSDs and reduce the beam spot to be 1 cm in diameter, in order to improve angular resolutions

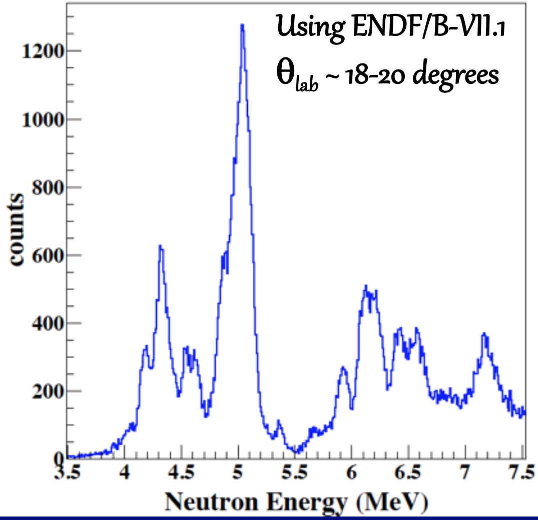
Anodized Ta_2O_5 targets

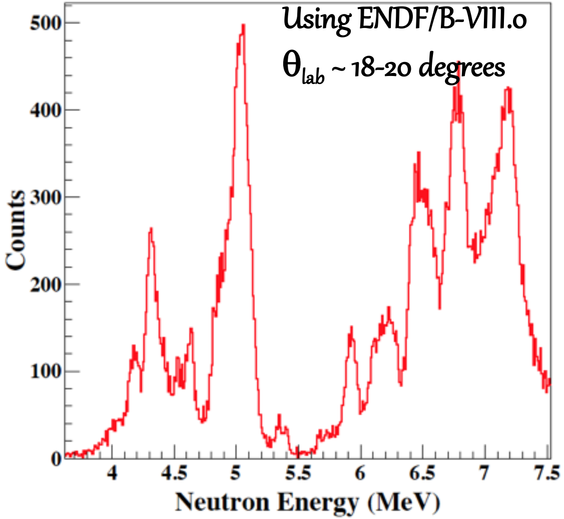




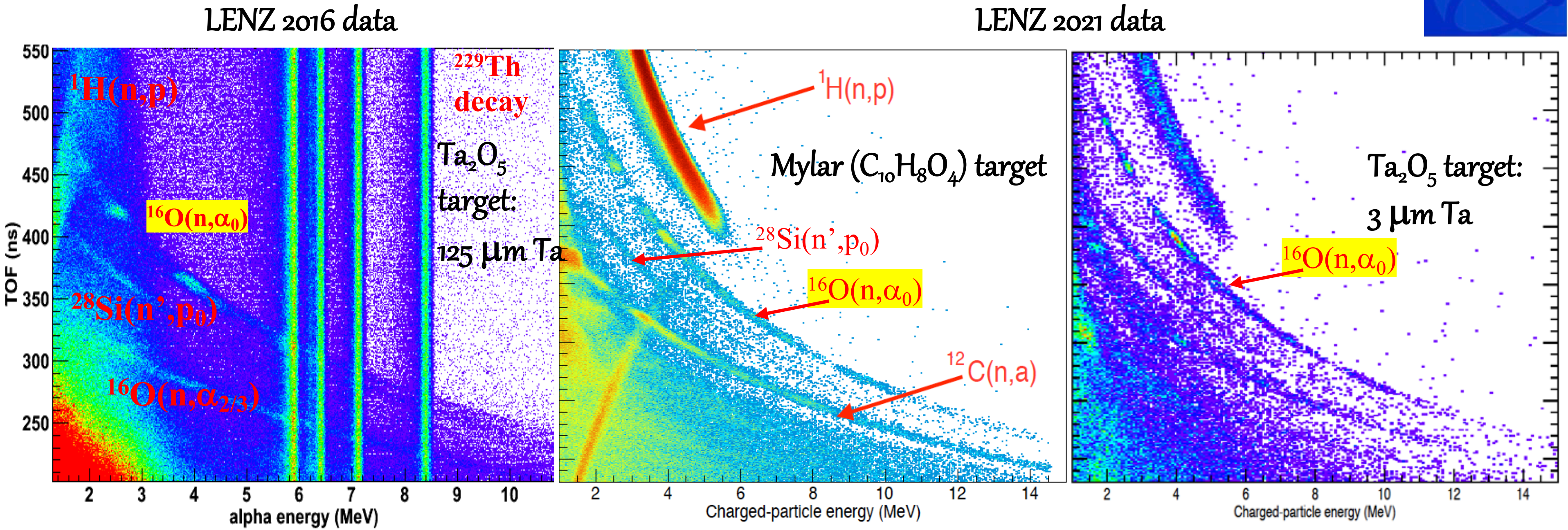
0.5 Tesla permanent magnet to sweep off any secondary charged particles
-dimensions: 55 X 35 X 30 cm^3
-bore size: 5 X 10 cm^2

MCNP simulation to reproduce LENZ data





$^{16}O(n,\alpha)$ yield comparison with different experimental configurations

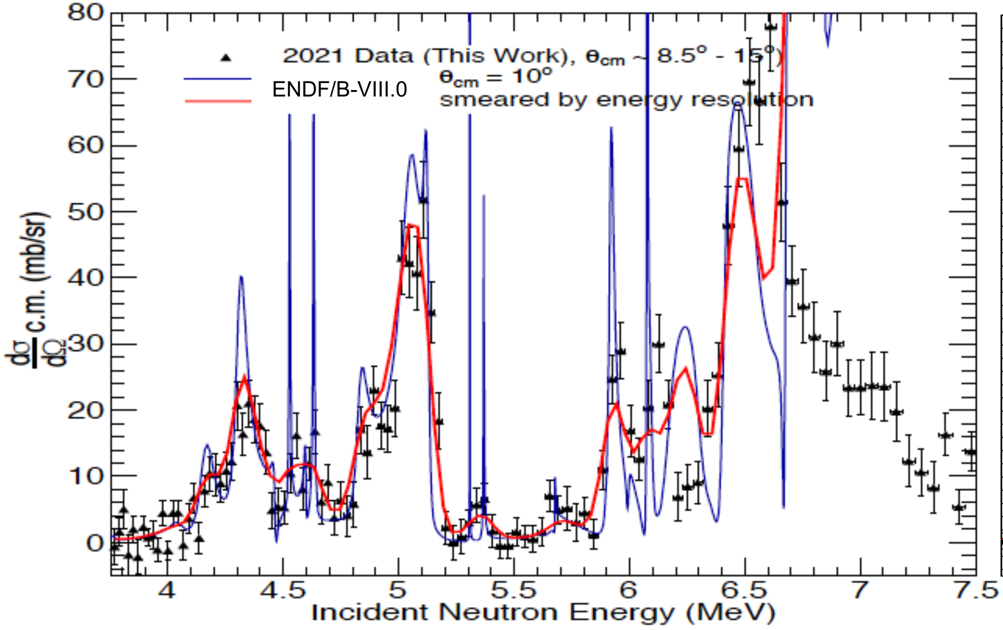


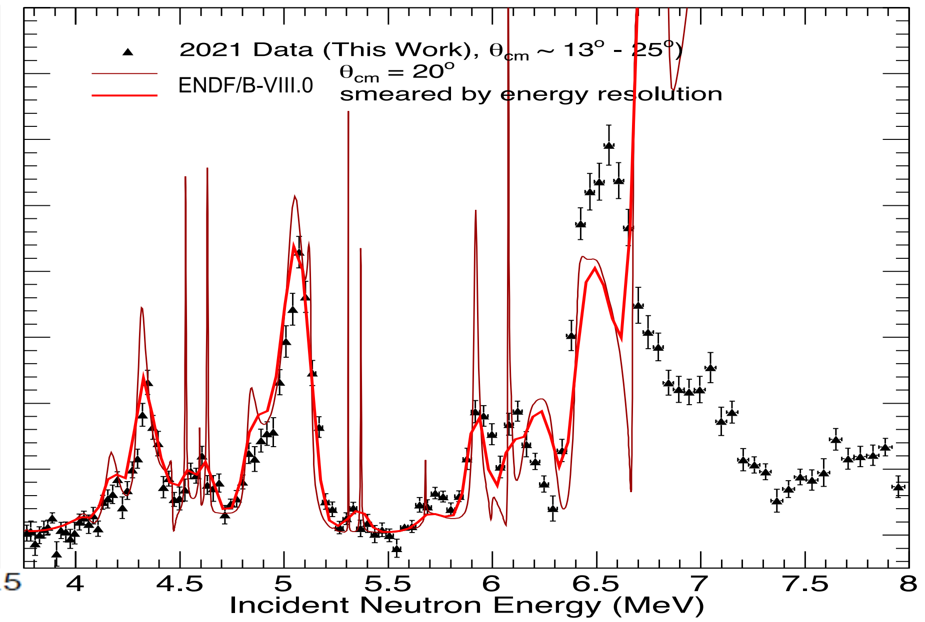
- LENZ 2016 data was taken using a 65 micron thick silicon strip detector in 2016
- LENZ 2021 data was taken using optimized experimental configurations and thinner Ta backing in 2021
- Ta_2O_5 targets with different thicknesses & Mylar ($C_{10}H_8O_4$) target for ratio method

2021 LENZ $^{16}O(n,\alpha_0)$ differential cross sections

1. Differential data can be directly used for R-matrix fits, with energy resolution functions
2. LENZ data well agreed with ENDF/B-VIII.0
3. Above 6 MeV, a new evaluation on angular distributions is needed with differential data sets
4. Differential cross sections are obtained up to 12 MeV in the neutron energy

Lee, Kuvin, et al. PRC (soon to be submitted)





$^{16}O(n,\alpha)$ reaction measurement summary

- With better understanding of systematic uncertainties associated with (n,z) reaction measurements at LANSCE through multiple reaction studies and validations with MCNP/GEANT simulations, we provided differential cross sections on the $^{16}O(n,\alpha)$ reaction, with experimental resolution functions. Results are prepared for publication.
- To reduce uncertainties for LANSCE measurements, we investigated;
  a. direct measurements of reaction cross sections
  b. ratio method with reference cross sections
  c. Forward Propagation Analysis by validating available libraries in MCNP
- Outlook on potential future measurements at LANSCE:
  -For better neutron energy resolution, diamond ring/mosaic array could be used for alpha detection
  -More detection angles around 90 deg. could be measured with an optimized setup